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AUTHOR	Cifuentes, Lauren; Hsieh, Yi-chuan Jane
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ABSTRACT

This study investigated skills that lead to generation of facilitative visualizations during study time for college age students. Specifically, the study examined the effects of teacher encouragement to generate visualizations, the effects of teacher encouragement and orientation to visualization, and the effects of the use of each of four visualization skills and rehearsal on test scores. An orientation prepared students in an experimental group to: (1) identify the underlying structure of a given text; (2) represent identified interrelationships; (3) generate pictorial as well s verbal study-notes; (4) visually connect concepts to prior learning; and (5) illustrate distinctive features of concepts. Participants were 75 undergraduate students in an introductory oceanography course at a large university. Students who showed interrelationships among concepts in their study-notes performed better on a test on science concepts than those who did not. No other significant effects were identified. (Contains 11 references.) (Author/AEF)

Visualization for Construction of Meaning During Study Time

Lauren Cifuentes
Yi-chuan Jane Hsieh
Texas A&M University

Abstract

This study investigated skills that lead to generation of facilitative visualizations during study time for college age students. An orientation prepared students in an experimental group to 1) identify the underlying structure of a given text, 2) represent identified interrelationships, 3) generate pictorial as well as verbal study-notes, 4) visually connect concepts to prior learning, and 5) illustrate distinctive features of concepts. Students who showed interrelationships among concepts in their study-notes performed better on a test on science concepts than those who did not. No other significant effects were identified.

Background and Theoretical Perspective

In Visual Communicating, Wileman defines visualization as the process of graphically or pictorially representing facts, directions, processes, data, organizational structures, places, chronologies, generalizations, theories, and feelings or attitudes (1993). In our study, we are interested in the power of student-generated visualization to facilitate learning. As Dewey remarked early in the 20th century, the work of instruction would be "infinitely facilitated" if teachers would see to it that their students were "forming proper images.... The image is the great instrument in instruction. What a student gets out of any subject ... is simply the images which he himself forms with regard to it." Dewey goes on to say that teachers would be wise to spend time "training the student's power of imagery and in seeing to it that he is continually forming definite, vivid, and growing images of the various subjects with which he comes in contact in his experience" (as cited in Wileman, 1993, p.7).

Student-generated visuals surpass illustrations in their effectiveness for instruction because they are more personally meaningful and relevant to students' understandings and prior knowledge, and because they contribute to construction of meaning (Anderson-Inman & Zeitz, 1993; Finke, 1990; Gobert & Clement, 1999; Papert, 1991). When students are able to manipulate images during knowledge construction, they tend to engage more in the meaning-making process and understand and remember concepts better than through the traditional transmission approach of instruction (Jonassen, 2000). Additionally, students' visualizations manifest the content and the structure of their knowledge of concepts, which provides their teachers with access to their levels of understanding.

Objectives

This study investigated the skills that lead to generation of facilitative visualizations during study time. Specially, researchers examine the effects of teacher encouragement to generate visualizations, the effects of teacher encouragement and orientation to visualization, and the effects of the use of each of four visualization skills and rehearsal on test scores.

Methods

The participants in this study were 75 undergraduate students in an introductory oceanography course at a large university. Twenty participants were sophomores, 22 participants were seniors, and others are juniors. Of the 75 students who attended class to participate, 27 were male and 48 were female. The participants represented 22 majors from throughout the university. Thirty participants were education majors. The other 45 students were from majors ranging from journalism to biology. Participants were randomly assigned to three groups in a posttest-only-control-group design. The data sources included: (a) test scores, (b) students' study notes, (c) "The Student's Questionnaire", and (d) the researchers' journals.

- **Unguided group**-- received 75 minutes of placebo instruction on use of bacteria to clean the Valdez, Alaska oil spill from the investigator. It then received an essay on the ocean's role in the greenhouse effect to study and students were given one hour for unguided, independent study prior to taking a test. Students handed in study-notes before being tested on the concepts of the text.
- **Encouraged-to-visualize group**-- received 75 minutes of the placebo instruction from the investigator. It then received the essay on the ocean's role in the greenhouse effect to study and

students were encouraged to visualize during study time. Students were given one hour for independent study prior to taking test. They handed in study-notes before being tested on the concepts of the text.

- **Oriented group**-- was asked to study two paragraphs of text and handed in their study-notes after studying. Based on the analysis of students' study-notes, the investigator was able to classify the students in this group as either visualizers or non-visualizers prior to receiving the orientation. Then, the group received a 75-minute orientation to visualization from the investigator. It then received an essay on the ocean's role in the greenhouse effect to study and students were encouraged to visualize during study time. Students were given one hour for independent study prior to the test. They handed in study-notes and were then tested on the concepts of the text.

Placebo instruction was designed so that all three treatment-groups would spend equal time with the investigator. For the placebo, the investigator presented a research study on the use of bacteria to clean up oil spills.

The oriented group received a 75-minutes orientation to visualization. Students examined short text in order to practice identifying underlying structure of that text that can be expressed as one of the following interrelationships— causal, oppositional, sequential, chronological, categorical, comparative, or hierarchical. The instructor then introduced the students to the concept of self-generated visualization as a study strategy. An advance organizer of the four skills and rehearsal was presented. The four skills were — (1) represent identified interrelationships, (2) generate pictorial as well as verbal study-notes, (3) visually connect concepts to prior learning, and (4) illustrate distinctive features of concepts. The instructor modeled generation of visualizations of the text on the overhead transparency. After each example was modeled, students practiced generating visualizations using each of the skills one at a time. They then shared their visualizations with other students and received feedback from the students regarding the effectiveness of the visualization at communicating the text, which was visualized. Because the training and practice time was limited, students had opportunities to visualize short pieces of text containing only one concept.

The easy for studying was 6 1/2 double-spaced pages of text written at the 12th grade level on the ocean's role in the green house effect. All participants took the test at the end of an hour study to determine the effects of the experimental treatment. The test contained 30 multiple choice questions, which was criterion referenced according to the objectives of the test student studied (r=. 86) and was validated by five oceanographers. The test scores were compared across groups.

In addition, three raters analyzed each student's study-notes and notes in the textual material to estimate the extent to which each student applied the four visualization skills when generating study-notes. Application of each skill was estimated on a scale of 1 to 5 on "The Visualization Skills Inventory" (Cifuentes, 1992). For example, if students made no attempt to show interrelationships they received a 1. If they showed interrelationships with numbering, highlighting, arrows, etc. they scored a 2. If they showed interrelationships through the generation of an outline or other primarily verbal means, they scored 3 points. If they showed interrelationships by creating a structural diagram or a verbal/pictorial representation showing one relationship, they scored 4 points. If they showed interrelationships by creating a structural diagram or a verbal/pictorial representation showing more than one relationship, they scored 5 points (see Figure 1). The interrater reliability was reported as r= .97 for showing interrelationships, r= .97 for balanced pictorial/verbal notes, r= .96 for showing relationships to previously know material and r= .99 for showing distinctive features.

Participants were classified as either visualizers or non-visualizers by examining the unguided group and encouraged to visualize group's study-notes that participants generated while they studied "The Greenhouse Effect" and by examining the study-notes generated by the oriented toward visualization group prior to the orientation. If subjects in each of the groups included any visualization in their study-notes, they were classified as visualizers.

After taking the test, all participants filled in "The Student's Questionnaire" that asked them to rate the extent that they had previously been exposed to the information in the greenhouse effect. To determine if groups varied in their prior knowledge of the textual material, an ANOVA was conducted. No difference was found. The questionnaire also asked students to report the extent to which they used their study-notes to rehearse when preparing for the test. The extent to which students' used their study-notes for rehearsal was estimated from question 1 on the questionnaire. Participants who scored a one or a two were categorized as non-skill-users. Participants who scored a three, four, five or six on were categorized as skill users. Additionally, students were asked to describe in detail the steps that they took to prepare for the test.

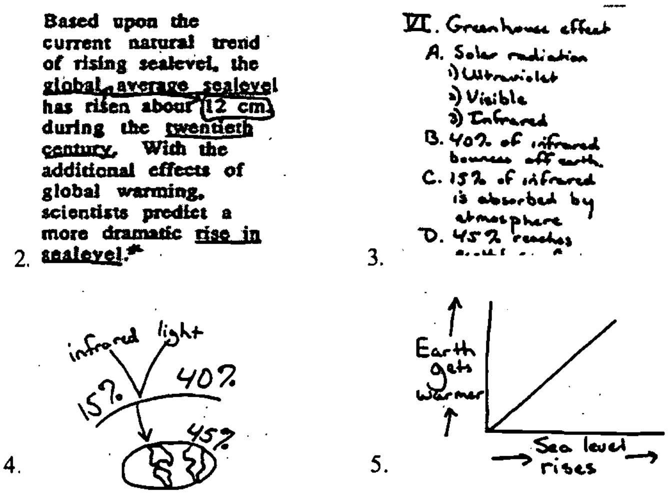

Figure 1. Skill users vs. non-skill users of showing interrelationships after the orientation (scale of 1-5 on each skill).

We applied content analyses approaches, as described by Emerson, Fretz, and Shaw (1995), to the researchers' journal entries, students' study-notes, and questionnaire results. During and upon completion of data collection, we used the two-phase process of content analyses, open coding and focused coding, to analyze the data and identify factors contributing to the effectiveness or lack of effectiveness of visualization as a study strategy for learning the text regarding ocean's role in the greenhouse effect.

Results

Based upon subjects' self-reports regarding their prior knowledge of the ocean's role in the greenhouse effect, it was determined that groups did not differ in their prior knowledge of the text. However, groups did differ in their use of study time. Most importantly, subjects in the oriented group wanted more study time to prepare for the test while students in the unguided group and the encourage to visualize group wanted less time to prepare for the test.

Regarding subjects' prior knowledge of visualization, 30 of the 75 subjects were education majors and were likely to have been exposed to visualization in education classes at the university. Informal interviews revealed that at least 5 education majors had been exposed to the strategy. Subjects were categorized as visualizers or nonvisualizers based upon their note-taking strategies prior to orientation to visualization. Nine of the 11 identified visualizers were education majors. Results of an ANOVA revealed that there were no significant differences between visualizers and nonvisualizers on the test (see Table 1).

Table 1. Summary of Numbers of Visualizers and Nonvisualizers Before Treatment Per Group and Test Means

	Unguided	Encouraged	Oriented	Total	Mean of Test Score
Visualize r	2	8	1	11	86.06 %
Non-visualizer	18	20	26	64	79.40%

There were no statistically significant differences identified between groups on test scores (see Table 2).

Table 2. Group Contrasts of Performance on the Test

Contrast	df	SS	MS	F	*p*	Effect Size
Unguided vs Encouraged	1	1.37	1.37	0.16	0.69	0.12
Encouraged vs Oriented	1	2.99	2.99	0.34	0.56	-0.24
Unguided vs Oriented	1	0.18	0.18	0.02	0.89	-0.14

alpha = .017

However, ANOVA revealed that students who showed interrelationships among concepts in their study-notes performed better on the test than did students who did not show interrelationships among concepts in their study-notes. No other statistically significant differences were found (see Table 3). In addition, Cohen's d indicated a positive medium effect size (d=0.57) for the pairwise comparison of those participants who showed interrelationships in their study notes and those participants who did not show interrelationships. Additionally, the d for the pairwise comparison of those students who balanced their notes pictorially and verbally and those students who did not was 0.37, and the d for those students who connected concepts to their prior learning and those students who did not was 0.34. These practical effect sizes indicate that showing interrelationships, balancing pictorially and verbally, and relating new concepts to prior learning made a significant difference on test scores (see Table 4).

Table 3. Five ANOVA's of the Effects of Four Visualization Skills and Rehearsal on the Test

Source	df	SS	MS	F	*p*
Show Interrelationships					
Between Groups	1	42.61	42.61	5.22	0.02*
Within Groups	73	596.06	8.17		
Total	74	638.66			
Balance Pictorially/Verbally					
Between Groups	1	20.94	20.94	2.47	0.10
Within Groups	73	617.72	6.46		
Total	74	638.66			
Relate New to Old Material					
Between Groups	1	17.41	17.41	2.05	0.15
Within Groups	73	621.25	8.51		
Total		638.66			
Show Distinctive Features					
Between Groups	1	6.72	6.72	0.76	0.38
Within Groups	73	631.94	8.66		
Total	74	638.66			
Rehearse					
Between Groups	1	2.22	2.22	0.26	0.61
Within Groups	73	636.44	8.72		
Total	74	638.66			

* $p<.05$

Table 4. Mean Scores and Standard Deviations on the Test for Those Who Used and Those Who Did Not Use Four Visualization Skills and Rehearsal

Skill Use in Study-notes	N	Test Score Mean	Standard Deviation	Skewness	Kurtosis	Effect Size[a]
Show Interrelationships	52	81.79	9.30	-0.27	-0.42	0.57
Did not Show Interrelationships	23	76.30	9.89	-0.04	-1.23	
Balance Pictorially/Verbally	39	81.82	9.40	-0.27	-0.40	0.37
Did not Balance Pictorially/Verbally	36	78.25	9.93	-0.08	-.097	
Relate New to Old Material	38	81.76	9.15	-0.33	-0.18	0.34
Did not Relate New to Old Material	37	78.50	10.17	-0.02	-1.00	
Show Distinctive Features	45	80.93	9.80	-0.20	-0.68	0.21
Did not Show Distinctive Features	30	78.86	9.72	-0.21	-0.79	
Rehearse	54	80.46	9.36	-0.29	-0.45	0.13
Did not Rehearse	21	79.19	10.91	0.20	-1.06	

Effect Size[a] = $(\overline{X}_{\text{show interrelationship}} - \overline{X}_{\text{did not show interrelationship}}) / SD_{\text{weighted}}$

The subjects who were oriented to visualization by the investigator were asked to describe their reactions to visualization as a study strategy. Comments were generally positive. Twenty-one of the 27 subjects used the words "helpful" or "useful" when expressing their opinions of visualization. However, opinions conflicted regarding the efficiency of generating visualizations. Some students felt that the time visualizing was time well spent; others felt that visualization took too much time for busy students whose time is limited. Opinions also conflicted regarding the amount of effort required to visualize. Some felt that visualization was difficult while others felt that it was easy. Conflicts like these indicate that individual differences between subjects contributed to their opinions of visualization. Perhaps the students who found that visualization was easy and time saving were visual thinkers, while those who found that visualization was hard and time consuming were not visual thinkers.

Educational Significance

The study is important in that it provides evidence in the growing body of visualization research. Based upon the findings, it is recommended that students be trained to represent interrelationships that are causal, oppositional, sequential, chronological, comparative, categorical and hierarchical. More powerful orientations to visualization need to be designed and implemented in order to investigate the effects of using visualization instruction on learning. Training sessions might need to be longer than the visualization orientation in this study and should provide more guidance, practice and feedback with textual material that is representative of the length of material that students are required to remember for classroom testing. A study similar to this study should be conducted allowing for flexible study time. In such a study, students would take the test when they want to so that time would not be a limitation. Based upon student behavior in this study, students trained in visualization skills might choose to spend more time-on-task and, therefore, might out perform untrained students.

Also, upon development of a reliable and valid measure of visual ability, aptitude-treatment-interaction studies should be conducted to determine ways to adjust instruction to students' individual differences. In this study, some students claimed that visualization was easier or less time consuming than other strategies while other students indicated that visualization was harder and more time consuming than other strategies. Perhaps visualization facilitates learning for visual thinkers but does not facilitate learning for non-visual thinkers.

As well as having differing effects on different learners, visualization may enhance memory more for certain kinds of content than for others. Both concrete and abstract prose recall have been shown to be enhanced by visualization. More studies are needed that compare visualization's effectiveness across various learning domains and various subject matter.

College level educators should not require students to visualize in preparation for a test because visualization may interfere with some students' efficient use of study time. However, we have shown that encouragement to visualize will not interfere with efficient study and may provide students with means to interact with the content they are studying. College level educators should encourage learners to visualize using learner techniques for representing interrelationships that are causal, oppositional, sequential, chronological, comparative, categorical, and hierarchical.

Future research should investigate the impact of the use of computer graphics software, such as AppleWorks™ and Microsoft™ Drawing and Painting tools on the effectiveness of student-generated visualizations. Cifuentes and Hsieh (2001) indicate that having students generate their visualization on computers offer several advantages over pen and paper, such as ease of subsequent revision and effortlessness of creating sophisticated looking graphics. However, learners may be distracted by the fun computer software and the computer graphics tools during learning. More studies need to be conducted in schools with reliable computers to further examine the effect of the use of computer graphics tools on visualization learning.

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